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Cyclic fatigue resistance: comparison of AF F-One and One Curve rotary instruments with Hyflex EDM OneFile in root canal therapy

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Abstract

Introduction: Cyclic fatigue is a major reason for file fractures as a complicated challenge in root canal therapy. The advantages of single-file rotary systems include time saving, cost-effectivenes and low risks of instrument fractures. This study selected an optimal file in terms of cost and clinical function by comparing cyclic fatigue among three files.

Materials and Methods: This in-vitro study employed artificial steel canal. Fifteen files of One-Curve, One-File and F-One were rotated according to their manufacturer's recommendation for speed and torque until they fractured. The number of cycles until fracture and the length of the fractured part were measured. The data obtaind were analyzed using the Kruskal-Wallis and Dunn's tests with a statistically-significant threshold of P<0.05.

Results: The mean fracture time of One-File was 456±14 seconds. The mean number of rotations was 3043±937 for One-File, 1333±234 for One-Curve and 462±116 for F-One, suggesting statistically-signficant diffrences (P<0.001). The mean length of the fractured part was 8.32±0.64 mm in One-File, 5.17±0.917 mm in One-Curve and 6.58±1.16 mm in F-One, suggesting statistically-signficant diffrences (P<0.001).

Conclusion: Resistance to cyclic fatigue in inside curved canals was the highest in One-File, followed by One-Curve and F-One, which cannot be used as an appropriate alternative to the other two types of file in single-file systems.

Keywords: Endodontics, fatigue fracture, NiTi instrument

1 INTRODUCTION

Endodontic treatments succeed only if the original shape of canals is preserved and iatrogenic errors are minimized during instrumentation. These errors comprise zipping, perforation, transportation and ledge formation. Using NiTi alloys has improved the flexibility and cutting efficacy of the instruments and decreased the errors cited in literature [1, 2].

The stress applied to NiTi instruments could reduce the success rate of treatments. Files fracture as a result of fatigue in 70% of cases. With no advance notice, fatigue fractures occur when instruments are bent and undergo alternating tension/compression stresses [3].

Manufacturers seek to characteristically improve endodontic instruments by modifying the design, manufacturing process and instrumentation protocols of NiTi instruments [4, 5]. Using single-file systems can simplify and expedite instrumentation at low levels of stress on NiTi files. Additionally, manufacturers recommended using single files have also made other changes to improve the NiTi instrument's characteristics [6].

One-Curve NiTi files (OC, MicroMega, Besancon, France) are made through the heat-treatment of Nickel-Titanium using a C-wire, which helps with memory control, curvature conservation and pre-bendability. The tip size is ISO 25 with a continuous taper of 6%. The cross-section of the file varies from the tip to the top of the cutting region. It is triangular at the tip and its cross-section is s-shaped near the shank. According to the manufacturer, this type of design is excellent in terms of cutting efficacy and provides a perfectly centered trajectory [6].

Hyflex EDM One-File (HEDM, Coltene, Whaledent, Altstatten, Switzerland) is manufactured through electrodischarge machining (EDM) using a special NiTi alloy. The manufacturer claims that the special alloy and EDM have improved the instrument's characteristics in terms of resistance to cyclic fatigue, controlled memory and pre-bendability. The tip size is ISO 25 and the file's taper is not continuous. The taper of the last 4 mm of the tip is 8% and the rest of the cutting region follows a

4% taper. The cross-section of the tip is quadratic, that of the middle trapezoidal and near the shank is almost triangular [7].

AF F-One (Fanta, Dental, Shanghai, China) is made of a heat-treated NiTi alloy. Many researchers evaluted its properties as a singe-file system (8-11). It goes not have controlled memory and is not pre-bendable. S-shaped flat-sided cross-section constitutes the main distinguishing feature of this file. Gambarini et al. Found the design to have improved resistance of the file to cyclic fatigue. The tip size is ISO 25 with a continous taper of 4% [12].

An appropriate single-file system is efficient in terms of instrumentation, preserves the original shape of canals and is highly resistant to cyclic fatigue [7].

To the best of the authors' knowledge, no studies have been yet conducted to compare the three types of the instruments cited. Given single-file systems as popular instruments among dentists, this study compared resistance to cyclic fatigue among One-Curve, HEDM One-File and AF F-One.

2 MATERIALS AND METHODS

The Ethics Committee of Shiraz University of Medical Sciences, Shiraz, Iran approved the present study protocol (IR.SUMS.DENTAL.REC.1399.040).

This study used the model proposed by De Melo' in 2002 and Aminsobhani in 2015. An artificial U-shaped computer-generated canal milled in a stainless block was used to stimulate root canal treatment. The canal's diameter was 1.5 mm, its curvature angle was 60 degrees, its curvature radius 5 mm and its length 2 mm. This artificial canal fit any endodontic files with any taper. The canal's inside was well polished and controlled high resolution digital microscope (Dino-lite digital microscope –Taiwan) .The canal was sealed using a 4-mm thick glass on its top.

This study selected 45 files from the three types, i.e. One-Curve (#25, 0.06, MicroMega, Switzerland), Hyflex EDM One-File (#25, Coltene, Switzerland) and AF F-One (#25, 0.06, Fanta, China).

A stereomicroscope with a magnification of x20 was used to confirm that the files were intact and undeformed before their application. The stainless steel block was fixed with a gripper to achieve a reproducible position. Liquid paraffin was utilized to reduce the friction between the files and the canal walls. An F20R 20:1 (NSK, Japan) handpiece attached to an EndoMate DT endo motor (NSK) was used to limit the speed and torque of each file within the theresholds recommended by the manufacturer. A dental loupe (Binocular Loupe system, USA Super Vu Galilean) was also employed to accurately record the fracture time of the files. The recommended speed was 400 rpm for HEDM, 450 rpm for One-Curve and 500 rpm for F-One. The recommended torque was also 2.5 N/cm for HEDM and One-Curve and 2.6 N/cm for F-One.

The interval between the rotation initiation and the fracture was recorded using a chronometer with a precision of 0.01 s. The number of cycles leading up to the fracture (NCF) was calculated through dividing the fracture time multiplied by the speed of rotation by 60. Furthermore, the length of the fractured segment was measured for each file.

NCF=fracture time (s)×rotational speed (rpm)÷60

2.1 Statistical analysis

The data were analyzed in SPSS-24 (IBM Corp., Armonk, N.Y., USA). The Kruskal-Wallis and Dunn's tests performed to compare the three groups in terms of NCF and the fractured length (FL) suggested significant differences ($P<0.05$).

3 RESULTS

The present study reported the highest and least resistance to cyclic fatigue in One-File and F-One, respectively. The mean fracture time was obtained as 456±14 s for One-File, 177±31 for One-Curve and 55±13 for F-One ($P<0.05$). The mean number of rotations obtained as 3043±937 for One-File, 1333±234 for One-Curve and 462±116 for F-One suggested statistically-significant differences ($P<0.000$). The mean fractured length obtained as 8.32±0.64 mm for One-File, 5.17±0.917 for One-Curve and 6.58±1.16 for F-One also denoted statistically-significant differences ($P<0.05$) (Table 1).

Table 1. Comparison of NCF, TtF and FL values (Mean±SD) between three rotary files.

	TtF(s)	NCF	FL(mm)
One File	456.48 ± 140.65	3043.21 ± 937.59 A	8.32 ± 0.64 a
One-Curve	177.84 ± 31.28	1333.83 ± 234.57 B	5.17 ± 0.91 c
AF F-One	55.51 ± 13.96	462.58 ± 116.32 C	6.58 ± 1.16 b
p value	=0.000	=0.000	=0.000

NCF, Number of Cyclic to Failure; TtF, Time to Fracture; FL, fractured fragment length; SD, standard deviation

Different superscript letters represent statistical significance

4 DISCUSSION

Despite the advantages of rotary files, unexpected fractures constitute their major problem [13]. Given cyclic fatigue as a major reason for file fractures [14, 15], acquiring knowledge about the resistance of files to cyclic fatigue is essential, especially in clinical practice [13, 16, 17].

Stainless steel canals have been used because extracted teeth did not have the same situation, and the test process wouldn't be standard.

To simplify the comparision of results and match the assumptions with those of previous studies, this study considered a 60-degree curvature angle and a 5-mm curvature radius for the stainless steel canal [16-18]. The present research was conducted to compare F-One, One-Curve and One-File as modern single-file rotary systems in terms of resistance to cyclic fatigue.

Comparing HEDM One-File, One-Curve, Vortex Blue and Protaper Gold in terms of resistance to cyclic fatigue, Uygan et al. Respectively reported One-File and One-Curve as the most resistant files [19]. The lower mean NCF in this study than that of the present research can be explained by differences in the curvature radius and curvature length of the canal tested.

Characteristics of a canal affect the file resistance [20]. The smaller the curvature and its angle, the more resistant a file [21]. The curvature reported by Uygan et al. Was larger than that of the present study by 3 mm. Measuring the fractured length, they also reported the longest fracture in One-File, which is consistent with the present findings. In contrast, different fractured lengths have been found in other studies [22-24].

The cross-section, mass and alloy type were found to affect the fractured length [12, 25]. The present study obtained a different fractured length from that of other studies owing to using a different cross-section and alloy type in the tested files. Estimaing the fractured length is clinically essential as the longer the fractured part, the easier the removal of the file from the canal. In this regard, the longest fractured part was associatd with One-File.

Gundogar et al. Compared HEDM, WaveOne Gold and One Shape [1] using a canal that resembled that of the present research. The relatively-higher NCF they found for HEDM can be explained by the different lubricants they used. Research suggests the high resistance of files with reciprocating movements to cyclic fatigue [26-29]. In contrast, Gundogar found the resistance of HEDM with only a rotational motion to exceed that of WaveOne Gold with a reciprocating motion.

Serafin et al. Used an artificial canal with the same characteristics as those of the present study canal. They compared resistance to cyclic fatigue between One-Curve and One Shape [6] and reported a lower NCF for One-Curve compared to that found in the present study. This difference can be explained by differences between the two studies in terms of the curvature length and inner diameter of the artificial canal. In fact, the C-wire technology coupled with the optimal cross-section design helped improve the resistance in the present research.

Gambarini et al. Found a flat-sided design to increase the resistance of F-One to cyclic fatigue [12]. In line with the present results, they reported different fractured lengths for different files, which confirms the effect of cross-section on the fractured length.

F-One as a rotary file has rarely been investigated in literature.

Increasing the rotational speed was found to precipitate file fractures [30-32]. In our study, the instruments were rotated according to the manufacturer's recommended speed to compare the files in their ideal condition, and for correct comparison of the cyclic fatigue NCF was used.

Lopes et al. Found canal properties such as curvature radius, arc location and arc length to affect the length of the fractures caused by cyclic fatigue [20]. They therefore used the same canal for all files.

Resistance to cyclic fatigue was found to rise with decreases in the cross-section of files [33, 34] given F-One as the file with the highest resistance at a low cross section; nevertheless, resistance to cyclic fatigue was the least in F-One given the more significant of other factors such as manufacturing process.

In line with literature, the present study reported the superiority of HEDM One-File in terms of resistance to cyclic fatigue [19]. This superiority was rooted in using EDM-manufactured C-wires and optimal selection of cross-section, diameter and rotational speed [1].

5 CONCLUSION

Resistance to cyclic fatigue was improved in the present study files by modifying their features. Measures taken to promote the resistance were the most effective in One-File. One-Curve was found to be the next after One-File in terms of resistance to cyclic fatigue. Despite its cost-effeciveness, F-One should not be used as an alternative to One-File or One-Cure in single-file rotary systems.

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